# Techniques of anaesthesia

The choice of anaesthetic technique depends on the type of surgery, patient risk-factors and the patient's preference. Options generally include general anaesthesia, regional anaesthesia and a combination of these techniques (Fig. 1).

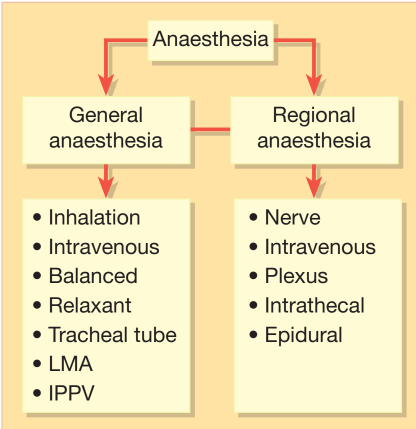


Fig. 1 **Anaesthesia options.**

(a) (b) (c)

Fig. 2 **General anaesthetic sequence.**

## General anaesthesia

General anaesthesia (GA) entails inducing a loss of consciousness while providing adequate operating conditions and stability of the essential physiological functions. To achieve this, the anaesthetist devises a strategy for each patient based on information acquired in a preoperative visit and knowledge of the complexity of the operation.

The induction of general anaesthesia is achieved with intravenous drugs in the majority of instances, but inhalation is a suitable alternative both for elective procedures, and in certain emergencies where the airway is compromised (see Fig. 2). Many children prefer inhalation as they are spared a needle insertion while awake. The agents used to induce anaesthesia are not always the same as for maintaining anaesthesia during surgery. The simplest general anaesthetic consists of using a single agent throughout for inducing and maintaining anaesthesia, and this can either be intravenous (using propofol) or inhalational (using sevoflurane).



## Balanced anaesthesia

There is debate about whether anaesthetized patients experience pain. Strictly speaking they cannot, as they are not conscious. However, hypnotic agents alone do not prevent the responses to surgical stimuli, such as increases in blood pressure and heart rate. The addition of analgesic agents, such as opiates and non-steroidal anti-inflammatory drugs, is thought by many to be an essential component of balanced anaesthesia (see Fig. 3). The combination of general and regional anaesthesia is also a popular option. Some practitioners advocate muscle relaxants as essential ingredients in a balanced anaesthetic technique. This view is strongly opposed by those who are concerned that paralysed patients who are inadequately anaesthetized are unable to indicate that they are awake.

For sick patients, techniques with minimal depressant effects on the heart are preferable. These are based on a high dose of narcotic analgesics (such as fentanyl) and a low dose of propofol or an inhalational anaesthetic agent (such as isoflurane). If appropriate, a regional technique should be added to reduce the adrenergic response to surgery.

## Emergence

Recovery from general anaesthesia depends on the elimination of agents by natural routes (lungs, liver and kidneys). Drugs with long elimination half-lives result in prolonged postoperative somnolence. Modern anaesthesia facilitates reliable hypnosis and analgesia coupled with rapid awakening and ability to function. Recent advances in anaesthetic and surgical techniques allow many operations to be carried out in day-surgery units.

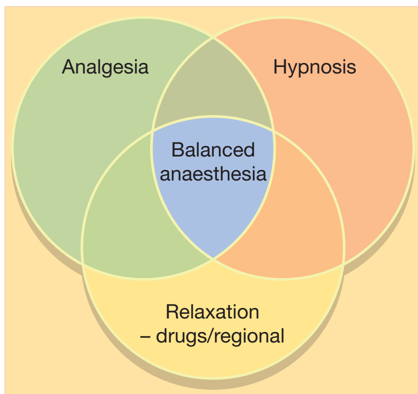


Fig. 3 **Balanced anaesthesia.**

## Tracheal intubation

Placement of a tracheal tube (TT) is not a prerequisite for all patients undergoing general anaesthesia (see Fig. 4). The main indications are risk of lung soiling with gastric contents and requirement for assisted ventilation of the lungs (intermittent positive pressure ventilation – IPPV). A laryngeal mask airway (LMA) is less traumatic and better tolerated than a tracheal tube and is used during the majority of general anaesthetics in the UK (see Table 1). Positive pressure ventilation may be administered via a laryngeal mask airway when there is no pulmonary pathology.

Table 1 **Examples of clinical decision-making**

| Indication | Considerations |
|---|---|
| Elective orthopaedic surgery | Regional, general or combination anaesthesia<br>Spontaneous ventilation – LMA |
| Intra-thoracic surgery | Usually painful and extensive surgery – balanced anaesthetic<br>Consider a combined regional/general anaesthetic technique<br>Requires IPPV to inflate the lungs – tracheal intubation is necessary |
| Adominal surgery | Balanced anaesthetic technique<br>Requires muscle relaxation – tracheal intubation (or LMA) and IPPV |
| Liver resection | GA with low-dose hypnotic and high-dose narcotic<br>Consider combination with epidural anaesthesia<br>Requires muscle relaxation – tracheal intubation and IPPV |

Fig. 4 **Anaesthetized patient with a tracheal tube.**

## Regional anaesthesia

There is a common misconception that regional anaesthesia is safer than general anaesthesia. In reality, when performed by an experienced anaesthetist, both techniques are extremely safe. Regional anaesthesia allows the provision of excellent analgesia and decreases the need for narcotics and hypnotic drugs. There is a choice between local blocks of specific nerves or plexuses, intravenous blocks of the upper limb (Bier's), subcutaneous infiltration and neuraxial blocks.

### Peripheral nerve blocks

The most commonly applied are dental nerve blocks, ocular nerve blocks for cataract surgery (see Fig. 5) and ring blocks of the fingers or toes. Other useful nerve blocks are intercostal nerve block, to alleviate pain in rib fractures or for the insertion of a chest drain and femoral nerve block for lower limb injuries.

### Plexus blocks

This technique is well established for upper limb surgery (e.g. brachial plexus block) and for relief of cancer pain (e.g. coeliac plexus block).

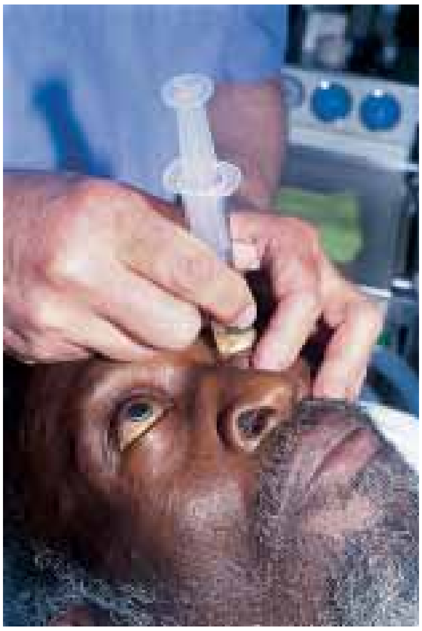

Fig. 5 **Administration of an eye block.**
Note: wearing of sherile gloves is indicated for this procedure.

### Intravenous blocks

Intravenous blocks are used for surgery of the upper limb (Bier's block), A tourniquet is applied to the arm and a short-acting local anaesthetic agent injected through a previously inserted intravenous cannula.

### Neuraxial blocks

Epidural and intrathecal blocks can be used as the sole anaesthetic for most surgery below the waistline or as an adjuvant of general anaesthesia for thoracic, abdominal, perineal and lower limb surgery. The decision to use neuraxial anaesthesia as the sole technique should be influenced by the health and the preference of the patient.

## Clinical scenarios

### Dental extractions

Anaesthesia for dental extraction should be provided by infiltration with local anaesthetic. The oral mucosa may be sprayed with topical lignocaine before needle insertion. General anaesthesia should be used only in exceptional circumstances, and then only in an operating theatre in an established hospital. In the UK general anaesthesia is overused for dental procedures.

### Cataract surgery

Local anaesthesia avoids the risks of postoperative sedation, nausea and vomiting, and the problems introduced by cardiac and respiratory disease.

### Fractured jaw after an accident

The protective laryngeal reflexes may be lost with danger of aspiration of blood, teeth and other debris. Protection of the airway is the first priority. This may be achieved by passing a tracheal tube via the nose with local anaesthesia (except when a fracture of the skull base is suspected) following which general anaesthesia may be induced.

### Elderly patient for internal fixation of a hip fracture

The elderly often suffer from medical problems. The usual choice is between general anaesthesia and neuraxial block. Studies have demonstrated a reduction in blood loss and respiratory complications with such operations when performed under neuraxial blockade.

### Techniques of anaesthesia

- Anaesthetic techniques include general anaesthesia, regional anaesthesia and combinations of these.
- Balanced anaesthesia entails the provision of analgesic agents in addition to hypnotic drugs.
- Tracheal intubation is seldom essential.
- Modern general and regional anaesthesia are extremely safe.
- Many operations are performed in day-surgery units.

# Sedation

An increasing number of minimally invasive procedures are carried out under sedation (Table 1). Such procedures are brief and cause minimal disturbance to the body's physiology, thus not justifying general anaesthesia, especially when patient cooperation is required. Sedation aims at alleviating the anxiety and discomfort associated with a procedure.

Sedation is not a discrete end-point, but lies on a continuum between complete wakefulness and general anaesthesia (Fig. 1).

Every patient responds to sedative agents differently. Sliding into general anaesthesia with loss of protective airway reflexes is an important complication of sedation. Sedative dose should be adjusted based on route of drug administration, drug interactions and patient's age and physical fitness.

Table 1 **Procedures carried out under sedation**

| Medical specialty | Procedures |
|---|---|
| Gastroenterology | Colonoscopy, gastroscopy |
| Chest medicine | Bronchoscopy |
| Dentistry | Extractions, root fillings, etc |
| Cardiology | Cardioversion, pacemaker, PTCA |
| Radiology | CT, MRI, etc |

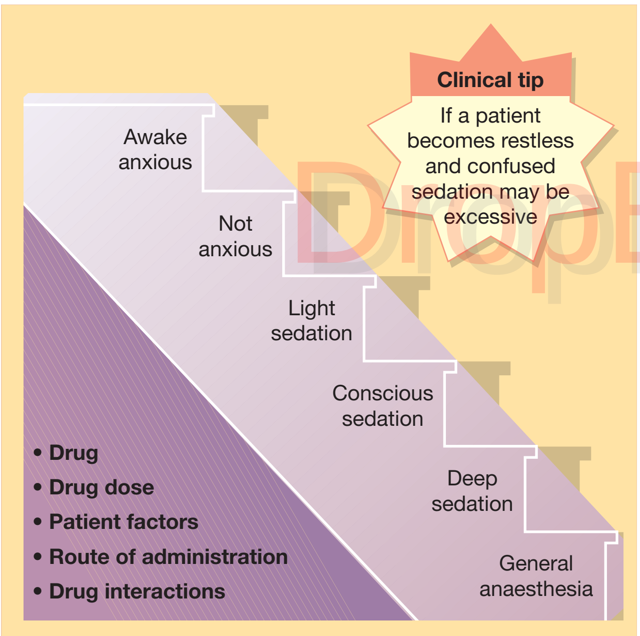


Fig. 1 **Sedation sliding scale.**

## Definition

Conscious sedation is a state where the patient:

- Has a depressed level of consciousness.
- Is free from anxiety.
- Is able to protect the airway.
- Is able to respond to verbal command.

Following conscious sedation, there may be amnesia despite continuous verbal communication.

## Patient selection and preoperative assessment

Appropriate patient selection reduces complications. Some patients are unsuitable for sedation and some procedures are too long or too painful. A preoperative assessment as for general anaesthesia should be carried out.

### History

In the presence of cardiac or pulmonary disease, reduced doses of sedatives may be needed. Hepatic or renal impairment may affect metabolism and excretion of sedatives leading to a longer duration of action. Previous adverse reactions to sedatives should be noted and current medication, last oral intake, and smoking or alcohol intake noted. Alcohol and smoking may increase the requirement for sedatives agents.

### Examination

The airway, the lungs and the heart should be examined. Laboratory and imaging investigations are not routinely needed unless specifically indicated.

Patients must be informed about the proposed procedure and sedation plan and written consent is mandatory. Patients should be fasted 8 hours for solid foods and 2 hours for clear liquids. Inadvertent over-sedation renders patients vulnerable to regurgitation and inhalation of stomach contents. Very anxious patients may benefit from an anxiolytic medication (e.g. temazepam) given orally 2–3 hours before the procedure.

## Prerequisites for safe sedation



The American Society of Anesthesiologists have issued recommendations as follows:

1) An anaesthetist should be present. It is reported in the USA that complications are less frequent when anaesthetists administer sedation. This recommendation is unlikely to be followed because there are not enough anaesthetists for the number of procedures carried out.
2) Vital signs should always be monitored. Oxygenation: the pulse oximeter is the most useful monitor. Evidence of unobstructed breathing movements should be sought throughout the period of sedation. Circulation: a non-invasive blood pressure device and an ECG monitor should be used in patients with hypertension or ischaemic heart disease. Consciousness: verbal contact with the patient should be maintained. In situations where it is not possible to speak, gestures such as 'thumbs up' can be used.

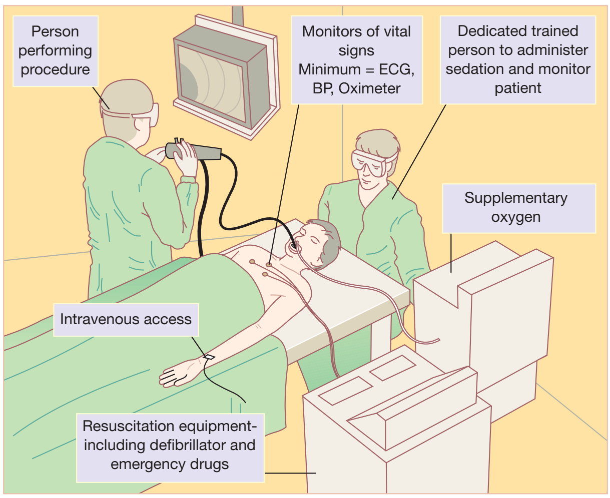


Fig. 2 **Sedation Unit set-up.**

3) The operator carrying out the procedure should not be in charge of monitoring the patient (see Fig. 2). Another member of the staff should do this. Resuscitation equipment including a defibrillator must be available.

## Sedative agents

Many agents have been used for sedation, including barbiturates, chlormethiazole, antihistaminc, neuroleptics, opioids, nitrous oxide, benzodiazepines and general anaesthetics. Modern sedation is based on midazolam or propofol and short-acting opioids.

### Opioids

Opioids have some sedative effects but should be used only if analgesia or blunting of airway reflexes is required. Morphine, pethidine, fentanyl and remifentanil are the most widely used. Their relative potency, duration of action and side-effects differ significantly. All can induce severe ventilatory depression, nausea and vomiting, dysphoria and itching. Respiratory depression is aggravated by concurrent use of benzodiazepines. Naloxone (40–200 μg iv) is an effective competitive receptor antagonist, capable of reversing the effects of opioids. It also has severe side-effects, including pulmonary oedema.

### Benzodiazepines

Benzodiazepines have important properties, inducing anxiolysis, amnesia and drowsiness. They are effective and safe and an overdose is rarely fatal. Midazolam has largely replaced diazepam; it has a shorter half-life (3 hours), causes less pain on injection and is more effective. The most serious side-effect is respiratory depression, which is more pronounced in the elderly. In an emergency, a competitive antagonist, flumazenil, is available to reverse the effects of benzodiazepines. Flumazenil is safe in a dose of 0.5–1 mg, but has a much shorter half-life than any of the benzodiazepines.

Propofol is a general anaesthetic, used for sedation in sub anaesthetic doses. It is as effective as midazolam but causes less amnesia. An advantage over the benzodiazepines is rapid recovery. Its effects can be titrated making it suitable for patient controlled sedation.

## Routes of administration

- Oral and rectal routes – slow onset of action and unpredictable absorption.
- Inhalation – used in dentistry.
- Oral and nasal transmucosal – fentanyl lollipops, useful in children.
- Intramuscular – useful when veins are difficult and rapid onset is needed.
- Intravenous – rapid onset and good titration, as a bolus or as an infusion. Continuos infusion allows good intraoperative sedation and is the choice for both midazolam and propofol.

### Patient-controlled sedation (PCS)

The patient may decide how much sedation is required, within certain limits (Fig. 3). The system is similar to patient controlled analgesia (PCA). The operator gives the first bolus and then the patient uses the system to maintain sedation. Propofol, with or without remifentanil, is a good choice for PCS.

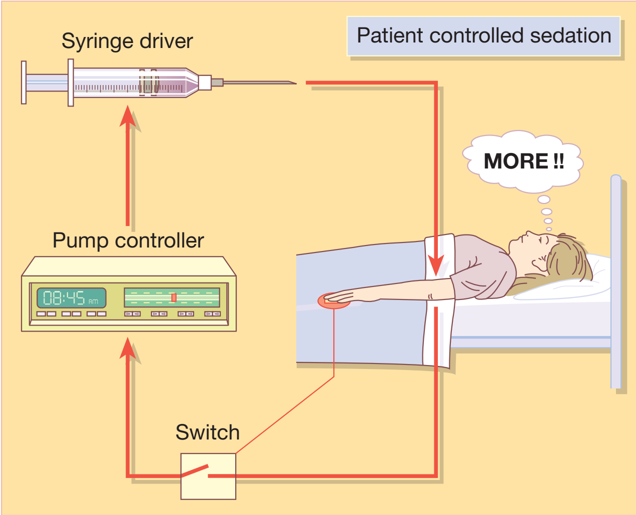


Fig. 3 **Patient-controlled sedation.**

## Complications

Good patient selection and careful drug titration minimize the following complications:

- Induction of general anaesthesia may lead to airway obstruction.
- Respiratory depression results in hypoxia and hypercapnia, which cause further sedation.
- Obtunded airway reflexes increase the risk of aspiration of stomach contents, especially during gastroscopy.
- Aspiration may lead to laryngeal spasm or bronchospasm.
- Hypotension or dysrythmias.
- Agitation and disinhibition may occur paradoxically following sedation, but may be related to hypoxia or hypercarbia.

## Recovery and discharge

Monitoring, particularly pulse oximetry, should be continued and vital signs recorded regularly until the patient is fully alert and orientated. If naloxone or flumazenil were given, monitoring must be continued for at least 2 hours.

In day-case surgery, the patient should be discharged into the care of a responsible adult written instructions with. Patients must not drive or operate heavy machinery until the following day.

### *Clinical case 19*

A 42-year-old man requires an investigative bronchoscopy and biopsy. He is a smoker and has a body mass of 130 kg.

*See comment on page 123–124.*

### Sedation

- The use of sedation for surgical procedures is on the increase.
- Effective and safe sedation is best provided by a trained anaesthetist.
- Suitable patient selection is important.
- Monitoring vital signs and oxygenation are essential and resuscitation equipment must be available.
- Short-acting agents given by infusion are preferable.
- A responsible adult should supervise patients for 24 hours.

# The stress response and nutritional therapy

The stress response evolved as an adaptation to tissue injury, burns, fractures and severe infection. It is characterized by neuroendocrine responses, activation of the sympathetic nervous system and of the coagulation–fibrinolytic network (see Fig. 1). There is an acute-phase response involving cytokines and other inflammatory mediators. When an animal is injured and is threatened by acute blood loss, the physiological manifestations of the stress response increase the chance of survival, however, in the context of surgery where we inflict injury as part of an intended therapeutic intervention, certain aspects of the stress response may be deleterious.

## Sympathetic activation

Sympathetic nervous system activation leads to increased oxygen requirements and may cause hypertension and myocardial ischaemia. The hormones released include cortisol, epinephrine (adrenaline), thyroid hormone, glucagon, and growth hormone, all of which increase blood glucose concentrations and induce catabolism. There is a concomitant decrease in anabolic hormones such as insulin, erthyropoietin and testosterone. Increased secretion of antidiuretic hormone leads to fluid retention and may result in hyponatraemia.

## Activation of coagulation

The hypercoagulable state predisposes patients to venous thromboses, which are important causes of hospital morbidity and mortality. Inflammatory mediators and cytokines cause pain and may precipitate hyperalgesia leading to chronic pain states.

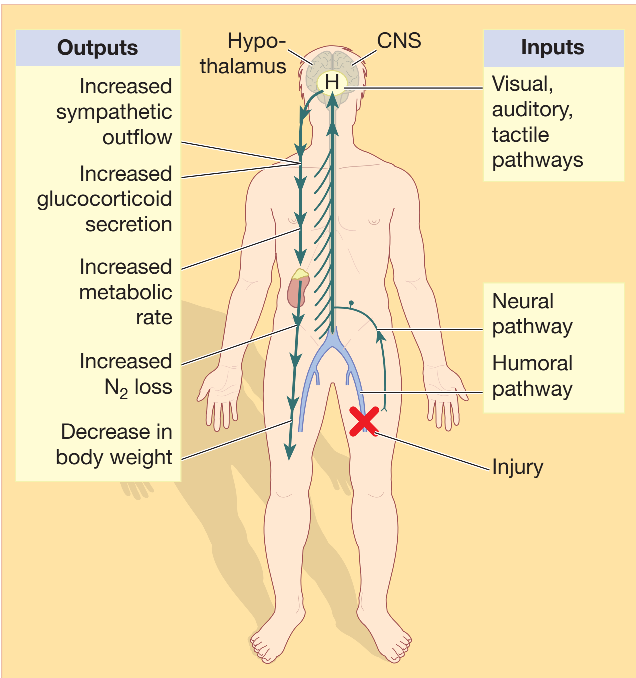


Fig. 1 **The stress response.**

## The body's response to surgery

Pain, nausea, ileus, vomiting, fatigue, sleep disturbances, hypoxia, hypothermia, pyrexia, anxiety, muscle wasting and immunosuppression are all features of the stress response to surgery. Acute-phase proteins such as C-reactive protein are released from the liver and fever often results.

There are various immunological changes associated with surgery. Macrophage and neutrophil activation is increased, whereas T cell-dependent antibody response and interferon-γ production is decreased. There is increased secretion of ACTH and leukocytosis may be present. Blood transfusion enhances postoperative immunosuppression.

Hypoxia results in decreased oxygen delivery to injured tissues and wound healing is impaired. The pain that follows surgical procedures may magnify the stress response causing a delay in restoration of function. The magnitude of the surgical stress response is related to the severity of surgical trauma.

## Decreasing the stress response

If the stress response indeed represents physiological adaptation to injury, it is debatable whether we should attempt to attenuate it. Nonetheless, there is evidence that blocking some of the manifestations through targeted interventions may improve outcome. Intravenous atenolol, for example, given at the time of surgery and continued for a week, has been shown to decrease the incidence of coronary events for those at risk for up to 2 years after surgery.

Multimodal analgesia improves pain relief and may abort the development of chronic pain syndromes.

Those who have postoperative hyperglycaemia may benefit from insulin, glucose and early feeding, thus interrupting the catabolic cascade. Thrombosis prophylaxis, such as low-molecular-weight heparin and elastic stockings, should be considered for all having major surgery. Stress potentiating factors (Table 1) may be avoided in an attempt to dampen the stress response.

Neuraxial (epidural and spinal) anaesthesia with local anaesthetics almost completely abolishes the early manifestations of the stress response to surgery below the umbilicus. Neuraxial blocks decrease both intraoperative bleeding and postoperative thromboses. They are associated with less sympathetic activation and may prevent pain.

Epidural anaesthesia, initiated before surgery and maintained for 48 hours post-surgery, prevents the decrease in protein synthesis and the increase in protein degradation that is typically seen with surgical stress.

Table 1 **Factors potentiating the stress response**

| |
|---|
| Anxiety and fear |
| Pain |
| Handling of viscera |
| Tissue injury |
| Blood loss and absorption of haematoma |
| Dehydration and starvation |
| Hypothermia |
| Hypxoxia and hypercarbia |
| Bacteraemia and release of bacterial toxins |
| Anaphylactic and anaphylactoid reactions |

High-dose opioids may blunt the stress response, but do not prevent it. Minimally invasive surgical procedures, such as the use of laparascopic techniques, may modify the surgical stress response. There is a subsequent reduction in protein catabolism, inflammatory mediators, pulmonary dysfunction and convalescence.

Prevention of intraoperative heat loss decreases the stress response, the wound infection rate and possibly even cardiovascular complications. Cytokine antagonists, free radical scavengers, glucocortcoids and other anti-inflammatory agents have been suggested as potential modifiers of the stress response. Neostigmine has recently been shown to be useful for the treatment of postoperative pseudo-obstruction and ileus.

It is extremely difficult to achieve stress-free anaesthesia and surgery. Yet, in striving to do so, we may hope to decrease an assortment of postoperative complications. Minimally invasive surgery may constitute an important step in this direction.

## Starvation and catabolism

In the surgical patient, the stress response coupled with the decreased intake of food leads to considerable weight loss. The patient may lose up to 30 g of nitrogen per day. In simple starvation (non-surgical), blood glucose concentration falls, and the patient only loses about 5–10 g of nitrogen a day. While providing nutrition may reverse simple starvation, the catabolism following surgery may be refractory to attempts at maintaining energy intake.

Maintaining a normal food intake preoperatively and providing early postoperative nutrition improves wound healing and reduces catabolism considerably.

### Oral dietary supplements

Whenever possible, oral or enteral feeding should be instituted. If the patient is able to eat, then diet can be supplemented with defined liquid formulae. Milk based formulae are more palatable, but are not suitable for patients with lactose intolerance. Milk free formulae can be elemental (free amino acids), semi-elemental (small peptides) and polymeric (whole protein). Lactose free polymeric formulae (Ensure®, Osmolite®) are commonly used and are iso-osmolar drinks containing 1 kcal/ml as 16% protein, 55% carbohydrate and 30% fat.

### Enteral feeding

Enteral feeding is used when the patient cannot or will not ingest adequate nutrients. Short term (< 6 weeks anticipated) tube feeding can be achieved by placement of a soft, small bore nasogastric or nasojejunal feeding tube (Fig. 2). Agents to improve gastric motility, such as metoclopramide and erythromycin, may be administered. A postpyloric tube allows enteral feeding despite gastric stasis. Long-term (> 6 weeks) tube feeding usually requires placement of a gastrostomy or jejunostomy tube. Commonly the tube is placed endoscopically (percutaneous endoscopic gastrostomy, PEG). Feeding schedules can be intermittent or continuous. During and for 2 hours after bolus intermittent feeds, the patient's upper body should be elevated. Complications of enteral feeding include tube misplacement, erosive tissue damage from the tube, tube occlusion, pulmonary aspiration of feeds, and diarrhoea.

Fig. 2 **Patient with a nasogastric tube.**

### Total parenteral nutrition (TPN)

The intestinal tract cannot be used in patients with persistent nausea and vomiting, intolerable postprandial abdominal pain or diarrhoea, mechanical obstruction, severe hypomotility, malabsorbtion or high output fistulae. In general, TPN should be considered when energy intake has been or is anticipated to be inadequate (<50% of daily requirement) for more than 7 days and enteral feeding is not possible. TPN is administered through a central venous catheter. Peripherally inserted central catheters (PICC) can also be used. Macronutrient solutions containing crystalloid amino acid solutions, glucose and lipid emulsion are infused at a rate of approximately 0.05g/Kg/hour. The complications of TPN are reduced with careful management and close supervision. Typical problems include pneumothorax and carotid artery puncture during line placement, fluid overload, refractory hyperglycaemia, electrolyte derangement, hypertriglyceridaemia, pulmonary embolism and thrombosis, catheter related sepsis and deranged liver function.

## *Clinical case 20*

A 66-year-old man has returned to the ward following a laparatomy for bowel cancer. He complains of pain (despite regular morphine injections), feeling bloated and nausea. Tympanic temperature is 34.7°C, blood glucose is 14 mmol/l and urine output is 20 ml/hour. His abdomen is distended and there are no bowel sounds. What measures might be taken to decrease morbidity and the risk of postoperative complications?

*See comment on page 124.*

### The stress response

- Certain aspects of the body's response to injury or the stress response may be deleterious following surgery.
- Epidural analgesia decreases the stress response to surgical procedures below the umbilicus.
- Minimally invasive surgery represents an important advance.
- Early enteral feeding is beneficial following surgery.

# Antibiotic prophylaxis

The risk of developing a surgical site infection (SSI) appears to be a balance between patient-related factors, microbial factors and wound-related factors (Fig. 1).

## Patient-related factors

Chronic illness, extremes of age or immunocompromise including diabetes mellitus and corticosteroid therapy are associated with an increased risk of developing SSI. The American Society of Anesthesiologists (page 7) score of 3 or more, indicative of a patient in poor medical condition, when combined with the type and duration of surgery has been shown to be predictive of the rate of SSI.

## Microbial factors

Enzyme production (*Staphylococcus aureus*), possession of polysaccharide capsule (*Bacteroides fragilis*) and the ability to bind to fibronectin in blood clots (*S. aureus* and *Staphylococcus epidermidis*) are mechanisms by which microrganisms exploit weakened host defences and initiate infection. Biofilm formation, exemplified by *S. epidermidis*, is particularly important in the aetiology of prosthetic material infections e.g. prosthetic joint infection (Fig. 2). The presence of a foreign body (such as sutures) reduces the inoculum required to induce SSI from $10^6$–$10^2$ organisms.

## Wound-related factors

Devitalized tissue, dead space, and haematoma formation are factors associated with the development of SSI. Historically, wounds have been described as clean, contaminated and dirty according to the expected number of bacteria entering the surgical site (Table 1).

## Prophylactic antimicrobials

The administration of antimicrobial prophylaxis for surgery has been shown to decrease greatly the incidence of postoperative infection, particularly where the inoculum of bacteria is high, such as in colonic or vaginal surgery, or where there is insertion of an artificial device, for example, a hip prosthesis or heart valve.

## Spectrum of antibiotics

Broadly speaking, infections associated with clean surgery are caused by Staphylococcal species and infections of contaminated suregry are polymicrobial in origin and comprise the flora of the viscus entered (e.g. *Esherichia. coli* and *B. fragilis* in colonic surgery). The antibacterial spectrum, low incidence of side-effects and tolerability of cephalosporins have made them the ideal choice for prophylaxis (Table 2).

The increasing prevalence of both methicillin-resistant *Staphylococcus aureus* (MRSA), against which cephalosporins are ineffective and *Clostridium difficile*-associated diarrhoea, a disorder associated with



Table 1 **Classification criteria of operative wounds according to level of bacterial contamination**

| Classification criteria | Description | Typical infection rates (%) |
|---|---|---|
| Clean wound | Non-traumatic, not inflamed, hollow viscus not entered | 1–3 |
| Clean–contaminated wound | Non-traumatic, entry of hollow viscus or mucous membrane surface with minimal spillage of contents | 8–10 |
| Contaminated wound | Fresh traumatic wound, entry of hollow viscus with spillage, especially colon<br>Operative site contaminated by infected bile or urine, acute inflammation present | 15–20 |
| Dirty wound | Old traumatic wound with devitalized tissue, presence of foreign body, faecal contamination or existing infection | 25–40 |

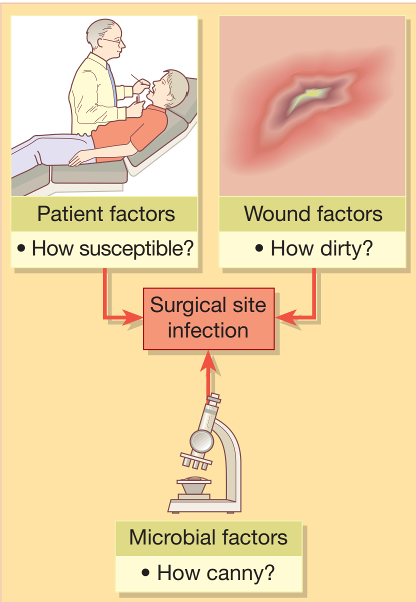


Fig. 1 **Factors predisposing to surgical site infection.**

Fig. 2 **Surgical site infection associated with recent implantation of a prosthetic hip.**

Table 2 **Antibiotic prophylaxis regimens for common surgical procedures (NB policy may vary according to the local situation)**

| System | Surgery | Antibiotic regime |
|---|---|---|
| Gastrointestinal | Upper bowel and biliary | Cefuroxime 750 mg iv |
| | Large bowel and appendix | Cefuroxime 750 mg + metronidazole 500 mg iv |
| | ERCP | Ciprofloxacin 750 mg po |
| Orthopaedics | Simple open fracture | Cefuroxime 750 mg iv |
| | Joint replacement and internal fixations | Cefuroxime 750 mg iv, 8-hourly for 24 hours |
| Gynaecological | Hysterectomy | Cefuroxime 750 mg + metronidazole 500 mg iv |
| | Caesarean section | Cefuroxime 750 mg iv after the cord is clamped |
| Urinary tract | TURP and cystoscopy | Ciprofloxacin 500 mg po |

cephalosporin use, may result in the substitution of other agents in future.

## Timing

The 'decisive period' is 0–2 hours before surgery. Three hours after surgical incision, prophylaxis is no longer effective.

## Duration

For most procedures a single dose is adequate. Prolonged surgery (> 3 hours) may necessitate a second dose. Prophylaxis should certainly be discontinued within 24 hours of the procedure.

## Prosthetic devices

Prophylaxis is given for 24 hours.

## Dirty surgery

Antibiotics are given therapeutically as full courses (5–7 days), e.g. bowel perforation, complex open fracture.

## Skull fractures

The literature does not support the use of prophylactic antimicrobials in closed skull fractures with or without CSF leakage. Antibiotic use may select resistant flora.

## MRSA

During an outbreak or when methicillin-resistant *Staphylococcus aureus* (MRSA) is endemic in the ward, vancomycin or teicoplanin prophylaxis should be used in cardiac, vascular and orthopaedic surgery.

Table 3 **Procedures for which prophylaxis for endocarditis is recommended**

| |
|---|
| **Dental procedures** |
| Respiratory procedures |
| **Tonsillectomy** |
| Surgery involving respiratory mucosa |
| Rigid bronchoscopy |
| **Gastrointestinal procedures** |
| Sclerotherapy of varices |
| Oesophageal dilatation |
| ERCP |
| Biliary tract surgery |
| Surgery involving intestinal mucosa |
| **Genitourinary procedures** |
| Prostatic surgery |
| Cystoscopy |
| Urethral dilatation |

## Infective endocarditis prophylaxis

Certain surgical procedures (Table 3) are associated with bacteraemia, which puts patients with certain cardiac abnormalities at risk of infective endocarditis (IE). Antibiotic prophylaxis is indicated in such cases (see Table 4).

The main cardiac indications are rheumatic heart disease, prosthetic heart valves, congenital heart disease, mitral valve prolapse with regurgitation, a previous episode of IE, and hypertrophic obstructive cardiomyopathy. Patients at particularly high risk are those with a prosthetic heart valve or a history of IE.

Antibiotic prophylaxis is not indicated in patients with coronary artery disease, previous bypass surgery or permanent pacemakers.

### *Clinical case 21*

A patient who is aged 67 years and has mitral stenosis after rheumatic fever as a child is undergoing a colonoscopy for chronic diarrhoea. Is antibiotic prophylaxis indicated?

*See comment on page 124.*

Table 4 **Suggested regimens for the prophylaxis of infective endocarditis (NB policy may vary according to the local situation)**

| Indication | Dosage | Timing |
|---|---|---|
| Standard general prophylaxis | Amoxicillin 3.0 g po | 1hour prior to procedure |
| | Amoxicillin 1.5 g po | 6 hours after |
| Unable to take oral medication | Ampicillin 2.0 g iv or im | 30 min prior to procedure |
| Allergic to penicillin | Clindamycin 600 mg po, or cephalexin 2.0 g po, or azithromycin or clarithromycin 500 mg po | 1h prior to procedure |
| Allergic to penicillin, unable to take oral | Clindamycin, adults 600 mg iv, or cefazolin 2.0 g iv or im, or vancomycin 1 g iv | 30 min prior to procedure |
| Gastrointestinal or genitourinary procedures | Gentamicin 1.5 mg/kg iv or im should be added to regimen | |

### Antibiotic prophylaxis

- Antibiotic prophylaxis if given appropriately is very effective.
- In the pathogenesis of surgical site infection (SSI) there is a balance between host defences, microbial virulence and wound factors.
- Wounds can be prognostically classified as being clean, clean–contaminated, contaminated or dirty.
- Timing – the 'decisive period' is thought to be 0–2 hours before surgery.
- Duration – prophylaxis should be discontinued within 24 hours of the procedure.
- Dirty surgery – antibiotics are given therapeutically as full courses (5–7 days).
- MRSA – requires the use of vancomycin/teicoplanin prophylaxis in cardiac, vascular and orthopaedic surgery.
- Prevention of bacterial endocarditis should be priority. A risk-assessment should be made on each case.

# Fluid management

Water is the major constituent of the human body, composing 60–80% of total body mass (Fig. 1). Body water is distributed in three compartments. About 60% of the water is intracellular and 40% is extracellular, of which 75% is interstitial fluid and 25% is intravascular (Fig. 2). The blood volume in adults is usually 5–6 litres. The average person has minimum obligatory daily fluid losses exceeding a litre and typically requires a daily fluid intake of about 2.5 litres.

There is significant fluid flux in the perioperative period. Patients presenting for surgery frequently have a fluid deficit, having been nil by mouth for at least 8 hours. This fluid deprivation is unnecessary as it is both safe and desirable to have unlimited clear fluids up to 2 hours before elective surgery. Some patients are at risk for profound dehydration, including those who have lost excessive volume through blood, urine, sweat, faeces or vomitus. Dehydration may be prevented in these circumstances through early administration of sufficient and appropriate intravenous fluids.

Table 1 **Features of hypervolaemia and hypovolaemia**

| | Hypovolaemia | Hypervolaemia |
|---|---|---|
| Suggestive history | Thirst, exercise, oliguria, blood loss, burns, trauma, diarrhoea and vomiting, diabetes, polyuria, diuretic therapy, orthostatic syncope, infection | Intravenous fluid therapy, heart failure, kidney failure, liver failure |
| Suggestive clinical signs | Dry mucous membranes, sunken eyes, tachycardia, orthostatic hypotension, pulsus paradoxus, thready pulse, decreased skin turgor, confusion, concentrated urine, decreased body mass, cold peripheries with poor capillary refill | Peripheral oedema, ascites, elevated jugular venous pulsation (JVP), basal lung crackles, confusion, sweating, increased body mass |
| Suggestive investigations | High urine osmolaliy, low urine output, high plasma urea, no increase in JVP and wedge pressure to fluid challenge, decreased cardiac output, swings in pressure trace of pulse oximeter and arterial line, decreased end tidal $CO_2$ | Low urine osmolality, high urine output, low plasma urea, exaggerated increase in JVP and wedge pressure to fluid challenge, evidence of cardiomegaly and pulmonary oedema on CXR, echocardiographic evidence of increased cardiac filling |
| Possible problems | Decreased venous return to the heart and hypovolaemic shock<br>Prerenal failure progressing to established renal failure<br>Vital organ hypoperfusion resulting in ischaemic cerebral, myocardial, renal, and liver injury<br>Inadequate tissue oxygenation leading to anaerobic metabolism and lactic acidosis | Cardiac failure<br>Cerebral oedema and raised intracranial pressure, which may cause irreversible brain damage<br>Pulmonary oedema causing intrapulmonary shunting leading to hypoxaemia and all its attendant problems<br>Impaired oxygen delivery at a tissue level |

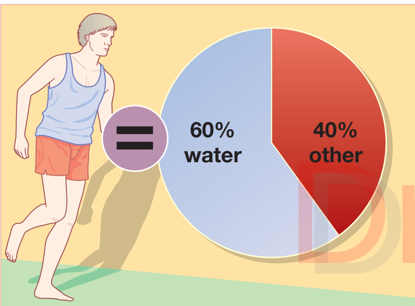


Fig. 1 **Water composition of the human body.**



During surgery obligatory fluid losses through urine (measured losses), sweating and breathing (insensible losses) continue. Additionally there is bleeding and third-space losses (sequestration of fluid into tissues, gastrointestinal tract and peritoneal space). Fluid losses are ongoing in the postoperative period. Throughout this time, patients are unable to fulfil their own fluid requirements and it falls to medical and nursing staff to provide adequate resuscitation.

Antidiuretic hormone and mineralocorticoids are released as part of the stress response to surgery. Urine output cannot thus be relied upon for evaluation of intravascular volume, although output persistently less than 0.5 ml/kg/hour is worrying. Not surprisingly, both hypovolaemia and fluid overload are common perioperative complications necessitating regular clinical assessment and accurate monitoring of fluid balance (Table 1).

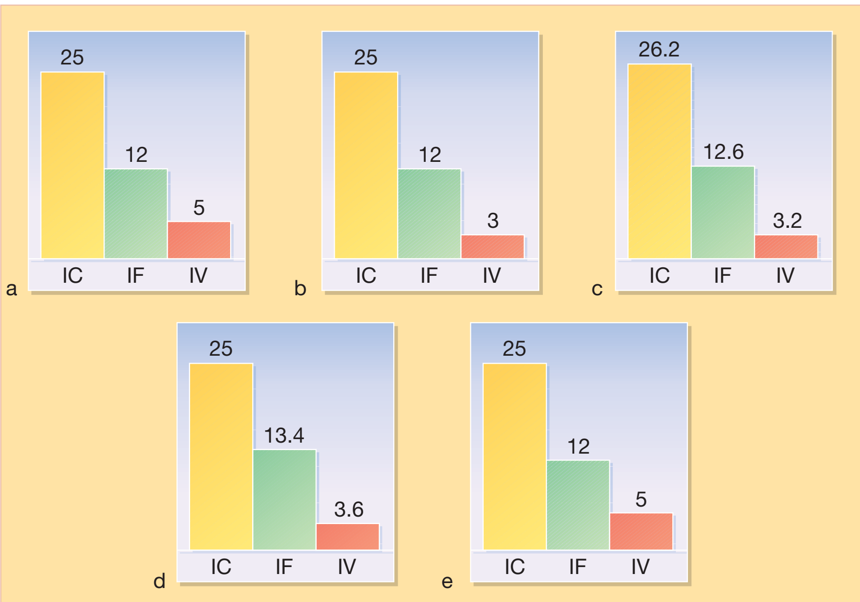


Fig. 2 **Body fluid distribution. (a)** Average 70 kg adult male. **(b)** Following 2 l acute blood loss. **(c)** Replacement of acute blood loss with 5% dextrose. **(d)** Replacement of acute blood loss with crystalloid. **(e)** Replacement of acute blood loss with colloid (IC = intracellular fluid, IF = interstitial fluid, IV = intravascular fluid).

## Perioperative fluid requirements

### Deficit and maintenance

Maintenance fluid requirements can be estimated as 1.5 ml/kg/hour or more conservatively as 1 ml/kg/hour when fluid restriction is indicated. Maintenance fluids, 5% dextrose being a

typical example, are administered to replace insensible losses from all three body compartments. Dextrose solutions are not good plasma volume expanders because the dextrose is metabolized and water distributes freely into all compartments. Pure water is not administered via the intravenous route, as it would flood into red cells and cause haemolysis.

In addition to obligatory water loss, there is concomitant electrolyte loss, particularly sodium, chloride, potassium and magnesium. For acute deficit and replacement it is usually necessary to administer fluids containing only sodium and chloride, as these are the most abundant extracellular ions. If sodium is not given, life-threatening hyponatraemia may result. An adult needs about 9 g of sodium daily. 0.9% saline (normal saline) contains 0.9 g of sodium chloride per 100 ml of water, or 9 g per litre, enough for daily salt requirements.

Excessive fluid replacement therapy with chloride-containing compounds may result in hyperchloraemia and metabolic acidosis. In order to avoid this it is sometimes appropriate to use solutions with lower chloride than sodium concentrations, such a Ringer-Lactate (Hartmann's solution).

## Replacement

Acute fluid losses deplete plasma volume more rapidly than other body compartments. Replacement should be with fluids which stay in the extracellular space. Balanced salt solutions (normal saline, Ringer's lactate), colloids and blood products satisfy this requirement. There is no evidence that colloids improve survival compared with crystalloids following acute losses (see Fig. 3).

Fig. 4 **Which fluid when?**

Acute fluid loss occurs with haemorrhage, burns, pancreatitis, peritonitis, diarrhoea, ileus and losses from the upper gastrointestinal tract. In sepsis, profound vasodilation coupled with loss of fluid into the interstitium results in intravascular hypovolaemia.

Blood loss should be replaced initially with a crystalloid solution (balanced salt solution) with a volume of three times the blood loss, as the crystalloid will distribute throughout the extracellular space. 2 litres of warmed Ringer-lactate is frequently the initial fluid resuscitation following major trauma. Subsequent replacement of blood loss may be with a colloid solution, which is temporarily confined to the plasma space (see Fig. 2).

Crystalloid administration may increase the risks of fluid overload and intersitial oedema (see Fig. 2). Colloids, on the other hand, will leak into the interstitial space within several hours and may cause platelet dysfunction. All patients who receive large amounts of fluids may develop a dilutional coagulopathy.

Debate rages about the most appropriate fluid in a given setting (Fig. 4). There is little evidence in the medical literature to provide reliable guidance. Currently, many doctors choose a judicious mixture of crystalloids and colloids. Starch and gelatine based colloids are popular because, theoretically, they remain in the plasma compartment longer. Albumin has become less popular owing to cost and evidence suggesting that in certain groups of patients, albumin administration may be associated with increased mortality.

### *Clinical case 22*

A previously healthy 55-year-old man with a body mass of 80 kg has undergone major colonic surgery for cancer. Intraoperative fluid therapy was appropriate and the haemoglobin was 11 g/dl following surgery. If he is expected to lose 500 ml of blood over the next 24 hours and is unable to take oral fluids, write an appropriate fluid chart for his needs.

*See comment on page 124.*

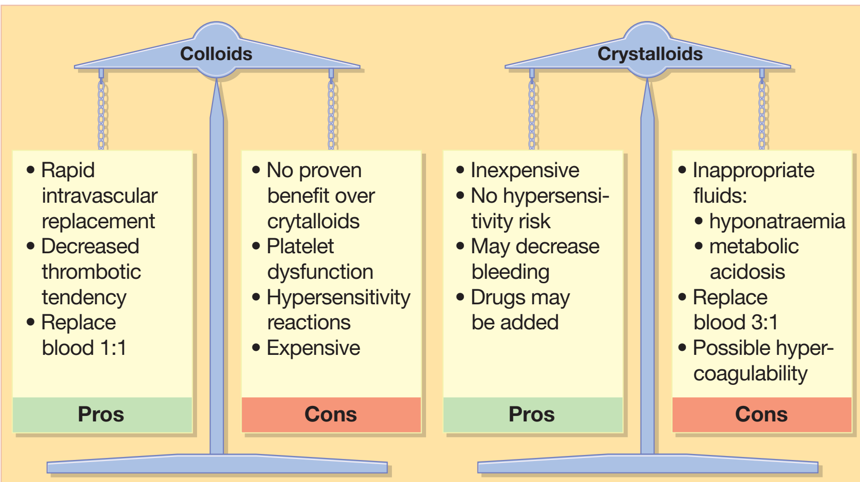


Fig. 3 **The pros and cons of colloids and crystalloids.**

### Fluid management

- Hypervolaemia and hypovolaemia are common perioperative problems.
- Fluid therapy should aim to replace fluid deficit, insensible losses and acute losses.
- A pure dextrose solution may be administered to replace some of the insensible water loss, but does not replace electrolytes and is unsuitable for acute losses.
- Dangerous hyponatraemia may result if dextrose solutions are administered exclusively.
- Balanced salt solutions and colloids are suitable for acute resuscitation.

# Blood products

Life is unsustainable without the constant flow of blood. Every minute the total blood volume circulates throughout the body. Nutrients, hormones and drugs are delivered in the blood to the various organ systems, and waste products are collected and couriered to the lungs, kidneys and liver for disposal. Haemoglobin is a specialized molecule in red blood cells, whose designated task is the efficient carriage of oxygen. When the body is threatened by infection, white cells, macrophages, cytokines, complement, killer cells and immunoglobulins meet the onslaught. Platelets and clotting factors are adapted to plug breeches and promote coagulation, thereby preventing exsanguination following injury.

## Transfusion

Healthy volunteers donate whole blood, which is fractionated into packed (red blood) cells, plasma, cryoprecipitate and platelets (see Table 1). These components may be life-saving when infused into the bloodstream of recipients who have inadequate haemoglobin levels, impaired platelet function or clotting disorders. Immunoglobins and specific clotting factors are also obtained from donor blood.

### Changes in transfusion practice

The term 'transfusion trigger' is used to denote the circumstances when transfusion would be reasonable. For many years it was advocated that surgical patients should receive a blood transfusion if the haemoglobin fell below 10 g/dl or if the haematocrit dropped below 30%, the '10/30 rule'. Blind adherence to this rule resulted in countless unnecessary blood transfusions with the attendant complications and costs.

No single laboratory value should be used as a trigger, rather several factors should be considered. These include age, underlying medical conditions, type and time-course of the anaemia, amount of anticipated blood loss and the presence of lactic acidosis or hypoxaemia. Even for critically ill patients, evidence suggests that transfusion may be withheld if the haemoglobin exceeds 8 g/dl. Treatment with haematinics or recombinant erythropoietin increases haemoglobin concentration and may subvert the need for transfusion.

Fresh frozen plasma (FFP) is frequently transfused inappropriately, with many doctors administering plasma whenever there is significant blood loss. In reality, only a fraction of normal clotting factor concentration is needed for adequate coagulation. FFP is indicated only if clotting tests confirm a coagulopathy. Empirical transfusion may be warranted if there has been massive blood loss (more than twice the blood volume) with inadequate haemostasis.



Platelet transfusion is usually indicated if the platelet count is less than $50 \times 10^9$/L at the time of major surgery or if there is documented platelet dysfunction. Aspirin therapy is not an indication for platelet transfusion. The effects on operative bleeding of newer anti-platelet drugs, like clopidogrel, ticlopidine and abciximab, are not well established. Thrombocytopenia and impaired platelet function are more common than clotting factor deficiencies following major trauma and surgery.

Table 1 **Blood components and their uses.**

| Component | Uses |
|---|---|
| Whole blood | Acute, large-volume bleed<br>Exchange transfusion |
| Packed red cells | Symptomatic anaemia<br>Major acute blood loss |
| Platelets | Thrombctyopenia with bleeding<br>Massive transfusion with dilutional coagulopathy and active bleeding<br>Platelet dysfunction (congenital or acquired) with bleeding |
| Fresh frozen plasma | Emergency correction of acquired and inherited coagulation defects<br>Massive blood transfusion with bleeding<br>Emergency reversal of warfarin therapy<br>Liver failure with bleeding |
| Cryoprecipitate | Low fibrinogen levels |

## Collection and storage

Blood products are screened for antibodies to Hepatitis B and C viruses, human immunodeficiency virus and syphilis.

Red blood cells are stored in bags containing additives and anticoagulant. Typical additive solutions are SAG-M (sodium chloride, adenine, glucose and mannitol) with citrate and CPD-A (citrate, phosphate, dextrose, adenine). The sugar, phosphate and adenine provide energy for the cells and render them viable for up to 35 days if stored at 4–6°C. Phosphate is added in an attempt to preserve 2,3 DPG levels in stored red cells. Depletion of 2,3 DPG reduces offloading of oxygen from haemoglobin by shifting the oxyhaemoglobin dissociation curve to the left. Citrate is an anticoagulant, which is rapidly metabolized by the liver following transfusion.

Platelets are stored at 22°C only for 5 days because of the risk of bacterial contamination. Plasma separated from whole blood may be rapidly frozen and stored at –30°C. Thawing FFP at 4°C and then refreezing to –30°C yields cryoprecipitate. Blood products in the UK are leukocyte-depleted to reduce the occurrence of febrile non-haemolytic reactions, as well as possibly reducing the transmission of prion disease, variant – Creutzveldt–Jacob.

## Pretransfusion tests

Before transfusion, a sample of the patient's blood must be collected and the blood group determined. The ABO and Rhesus groups are of major clinical significance, since antibodies to donor red cells can cause fatal transfusion reactions.

The patient's blood is tested for red cell antibodies and is mixed with the donor red cells (cross-match) to ensure compatibility. The bedside check of patient identity against the blood units is vital to prevent fatal errors (Fig. 1). Two health professionals, both of whom


Fig. 1 **Crucial items to check prior to administering blood.**

| Table 2 **Complications of blood transfusion** | | |
|---|---|---|
| **Acute complications** | **Cause** | **Comments** |
| Haemolytic transfusion reaction (mismatch) | ABO incompatibility | Usually due to clerical and administrative errors |
| | | 10% mortality |
| Febrile non-haemolytic reaction | Antileukocyte antibodies | Decreased with leukocyte-depleted blood |
| Urticaria | Antibodies to infused plasma proteins | |
| Anaphylaxis | As for urticaria | |
| Transfusion-related acute lung injury (TRALI) | Donor plasma has antibodies to patient's leukocytes | May be fatal |
| | | Occurs with massive transfusion |
| Dilutional coagulopathy | Massive transfusion | |
| Septic shock | Bacterial contamination of blood products | |
| Congestive cardiac failure | Volume overload | |
| Hypothermia | | Warm blood if large volume transfused |
| Hyperkalaemia | | Usually transient |
| Hypocalcaemia | | Usually transient |
| Citrate toxicity | Massive transfusion | Treat with iv calcium chloride |
| **Delayed complications** | | |
| Delayed haemolytic transfusion reaction | Antibodies to donor red cell antigens which are not detected in the cross- match | |
| Graft versus host disease | Donor T cell response against immunodeficient recipient | Often fatal |
| Immunosuppression | Related to white cell exposure | Cancer recurrence and postoperative infection |
| Viral infection | Failure to detect virus in donor blood | Risk depends on virus: |
| | | HIV $<$ 1 in 3 × $10^6$; HBV/HCV $<$ 1 in 200 000 |
| Iron overload | Multiple transfusions | |

sign that they have checked the blood before transfusion, must perform the check. In emergencies when there is insufficient time to wait for cross-matched blood, group O Rhesus-negative blood may be given. Specific compatibility is not necessary for plasma, which is pooled from multiple donors, or platelets, which may be pooled or from a single donor.

## Complications of transfusions

The complications of red cell transfusions are shown in Table 2. The major risk with plasma and platelets is infection. Following a platelet transfusion, patients develop antibodies to platelet antigens. There is a high risk of thrombocytopenia with a subsequent platelet transfusion. If a high volume is transfused there is a danger of hypothermia unless the blood is warmed (Fig. 2).

## Alternatives to homologous transfusion

Autologous blood transfusion involves the use of the patient's own blood, thereby avoiding several of the hazards of blood transfusion. However donation prior to surgery is generally not considered cost-effective. Acute normovolaemic haemodilution entails removal of blood at the start of surgery and simultaneous replacement with crystalloid or colloid. This lowers haematocrit so that fewer red cells are lost. Collected blood, rich in cells and clotting factors, is transfused following surgery. Intraoperative blood salvage systems have been developed, which allow collection and re-infusion of blood during surgery. Red cell substitutes offer an alternative to blood transfusion, but are currently expensive and of limited efficacy.

Fig. 2 **Patients during and after surgery may receive massive transfusions of blood and blood products with all their attendant complications.**

### *Clinical case 23*

A patient receiving a blood transfusion on the ward develops pyrexia of 38.3°C and the heart rate increases to 110 beats/min. The patient complains of sweating and mild itching. What should be done?

*See comment on page 124.*

### Blood products

- Whole blood is rarely required.
- Packed red cell transfusion is seldom indicated when the haemoglobin exceeds 8 g/dl.
- There are numerous complications associated with blood transfusion.
- Two health professionals should check blood before it is administered.
- Empirical transfusion of platelets and FFP should be avoided.

# Oximetry and capnography

The pulse oximeter provides a continuous, non-invasive, indirect in vivo measurement of the proportion of oxyhaemoglobin to total haemoglobin in arterial blood. It estimates the oxygenation of arterial blood, thus replacing invasive measurements of $PaO_2$ in samples of arterial blood. The pulse oximeter has become indispensable for monitoring patients receiving sedation or anaesthesia and for those in the intensive care unit.

Pulse oximetry was developed following a chance observation in 1971 that arterial pulsations (observed in two signals received from an ear oximeter transmitting light at 805 and 900 nm) showed a change in relative amplitude during breath-holding. It took another 15 years to develop a device for clinical use and for its acceptance in routine clinical monitoring.

Pulse oximeters display *functional saturation* in %, which represents the proportion of oxyhaemoglobin in the sum of oxy- and reduced haemoglobin according to the equation

$$\text{Sat }(\%) = \frac{100 \times HbO_2}{(HbO_2 + \text{Hb-red})}$$



## Oximetry

At 660 nm (red) and 940 nm (infra-red) light absorption coefficients are different for haemoglobin and oxyhaemoglobin allowing the measurement of the relative amounts of the two states. Two additional beams of different wavelengths are needed to measure methaemoglobin or carboxy-haemoglobin. Standard bench oximeters measure absorption at 4 or more wavelengths.

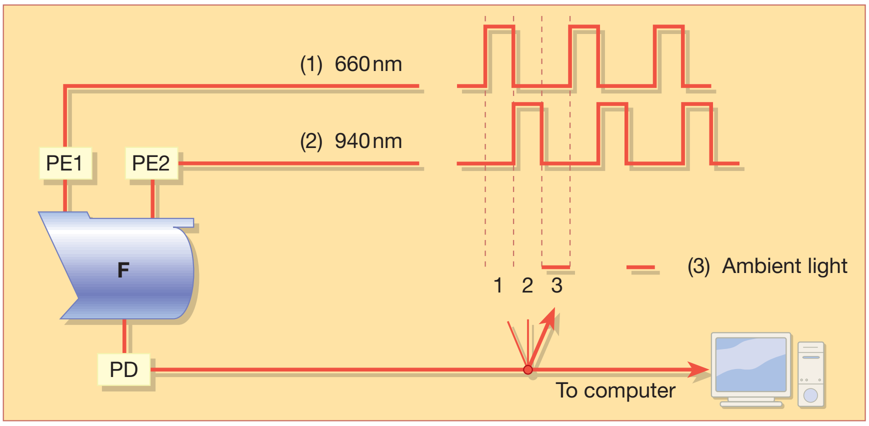


Fig. 2 **Diagram of the pulse oximeter**. F = finger, PE = light-emitting diodes, PD = photodiode. The output of the detector responds in sequence to the two light-emitting diodes and to ambient light.

### Pulse oximetry

Pulse oximeters use beams at 660 and 940 nm. A finger probe (see Fig. 1) contains two light-emitting diodes on one side of the finger and a single photodiode on the other, to pick up the radiation transmitted through the tissue. Each diode emits short pulses of light and the frequency of switching between the two wavelengths is very rapid (> 400 Hz). Between the light pulses there is a short interval without emission when the detector picks up ambient light in order to subtract this signal (see Fig. 2).

The pattern of the signal in a finger probe is in Fig. 3. There are two components of the signal: a steady component arising from the non-vascular parts of the tissue, the venous blood and non-pulsatile arterial blood, and a pulsatile component, typically 2% of the steady one, arising from the alternating filling and emptying of the arterioles with each cardiac pulsation. Its amplitude depends on the arterial pressure wave and on the proportion of oxyhaemoglobin. A decrease in oxyhaemoglobin leads to a decrease in amplitude of the pulsatile signal picked up from the 940 nm diode and an increase in that from the 660 nm diode.

Pulse oximeters have an integral computer which first calculates the ratios between the pulsatile and steady components of the signals at 660 and 940 nm, and then the ratio between these two ratios is calculated. The final reading in % results from a complex calculation following an algorithm derived from simultaneous measurements made in a bench oximeter during hypoxic experiments in volunteers. All pulse oximeters are calibrated at the factory empirically. Accuracy varies from instrument to instrument and values of less than 60% are unreliable.

Several factors can cause false readings or prevent pulse oximeters from functioning:

Fig. 1 **Pulse oximeter finger probe in situ perioperatively.**

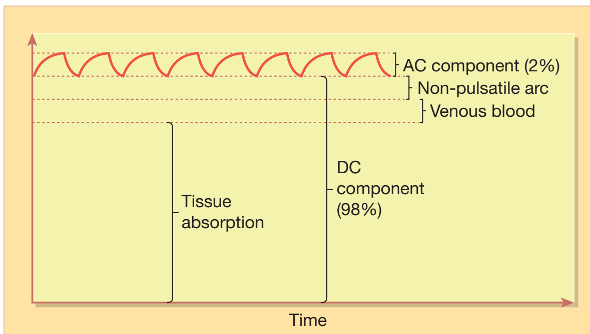


Fig. 3 **Simplified trace of the reconstituted signal picked up by the photodiode of a pulse oximeter at one wavelength.**

- Methaemoglobinaemia and carboxyhaemoglobin cause over-estimation errors. Fetal Hb and hyperbilirubinaemia do not interfere with readings.
- Artefact – poor peripheral perfusion (hypovolaemia, hypothermia, left ventricular failure or compression of supplying arteries by BP cuff) results in a poor pulsatile signal and unreliable or unobtainable reading.
- Artefact – movement of the probe or of the limb where the probe is applied may cause erroneous readings, especially if the movement is rhythmic.

Most pulse oximeters alert the user to a poor signal, meaning that the pulsatile fraction of the light received is less than 0.5% of total light; the machine alerts the user to the unreliability of the reading.

## Capnography

Capnography is the measurement of carbon dioxide ($CO_2$) in respiratory gases (see Fig. 4). It is a very useful monitor for patients under anaesthesia and for those in intensive care units for the following reasons:

- It indicates if the lungs are being ventilated (can be linked to an alarm).
- It excludes oesophageal placement of a tracheal tube.
- End-tidal $CO_2$ can be used as a guide to adjust mechanical ventilation.
- Short-term variations in end-tidal $CO_2$ indicate variations in cardiac output or sharp changes in metabolic rate (e.g. malignant hyperthermia).
- Variations in the shape of the capnograph waveform indicate changes in dead space (e.g. in pulmonary gas embolism) or maldistribution of ventilation (e.g. in bronchospasm).

The most commonly used capnograph uses the infra-red light absorption property of $CO_2$ to measure its concentration. The main components of air (nitrogen and oxygen) do not absorb infra-red light. Gases and vapours used in anaesthesia (nitrous oxide, isoflurane) absorb infra-red light with a characteristic spectrum, different from that of $CO_2$. The gas sample passes through a chamber crossed by an infra-red beam directed at an infra-red detector in the opposite side. The larger the content of $CO_2$ in the sample, the lesser is the energy of the beam reaching the detector. Available instruments, measuring $CO_2$, $N_2O$ and a volatile anaesthetic, are provided with three infra-red beams, at different wavelengths, chosen to coincide with the highest peaks of the infra-red absorption spectrum of each gas.

Most clinical capnographs (sidestream) contain a suction pump pulling a small amount (50–200 ml/min) of gas from the patient's airway via a long sampling tube (Fig. 5), into the analysing cell within the apparatus, thus introducing a delay in the reading (0.1–0.3 seconds) due to the travelling time between the point of sampling and the sensor. Instruments are also available with a miniaturized sensor placed directly on the breathing system (mainstream), avoiding some problems of the sidestream sampling. This sensor, however, is vulnerable to physical damage and is very expensive.

### *Clinical case 24*

A patient admitted to the intensive care unit, with a provisional diagnosis of an overdose including an opiate drug, has been urgently intubated and placed on a mechanical ventilator following a period of deterioration of efforts to breathe spontaneously. Despite normal ventilator settings for the patient's size and absence of physical signs and history of lung pathology, the readings obtained from the pulse oximeter show a saturation of 81% with a clear, good amplitude pulsation. The capnograph trace shows a slow rise in $CO_2$ concentration during expiration, never reaching a plateau. There are no leaks or obstructions in the breathing system linking the patient to the ventilator, inspired oxygen concentration is 60% and the chest wall moves with each ventilation cycle.

*See comment on page 124.*

### Oximetry and capnography

- Pulse oximetry and capnography have become indispensable monitoring devices in the settings of anaesthesia and intensive care.
- Both techniques are non-invasive.
- Pulse oximetry indicates oxygenation of arterial blood and capnography indicates adequacy of ventilation.
- Data provided by these instruments is susceptible to artifacts.
- Knowledge of the operating principles of pulse oximetry and capnography is desirable for appropriate interpretation of the readings.

(a)

(b)

Fig. 4 **(a)** Monitor showing oximeter and capnograph traces. **(b)** Portable combination pulse oximeter and capnograph.

Fig. 5 **Sampling tube of a 'sidestream' capnograph.**

# Postoperative recovery

At the end of a surgical procedure, irrespective of whether it was carried out under regional or general anaesthesia, patients can have an unstable cardiovascular system. In addition, those who have had a general anaesthetic may still be unconscious and unable to protect or maintain their airway. Clearly, it would be unacceptable to return such patients directly to a general ward.

Fig. 1 **One-to-one attention of staff is vital in the recovery room.**

## The recovery room

For the post-anaesthetic patient, the recovery room bridges the period leading to the return of consciousness, full return of protective airway reflexes and resumption of spontaneous respiration and cardiovascular stability (depending upon the type of anaesthetic and surgery). In addition to supervising the return of normal physiological function (See 'Core functions', below), recovery room staff ensure that the patient is not bleeding, nauseous or hypothermic, has adequate pain relief and has been prescribed appropriate analgesia and intravenous fluids prior to return to the ward (Table 1). Depending upon local guidelines, and the type and nature of the anaesthesia and surgery, patients will remain in the recovery room for between 30 minutes and 1 hour.

In some situations, particularly after major surgery, some patients may require an extended period of close supervision of the sort provided in the recovery room. This may be because of continuing cardiovascular instability, the need for respiratory support and monitoring, increased risk of bleeding or problems related to an underlying medical condition. These patients may be admitted directly to a high-dependency unit (HDU – sometimes referred to as a progressive care unit, PCU) or to an intensive care unit, until the required degree of physiological stability has been achieved.

The recovery room provides, on a one-to-one basis (Fig. 1), staff skilled in airway management and basic life-support. Recovery staff will closely supervise the post-anaesthetic patient until consciousness has returned. Thereafter, the patient will be regularly monitored until discharge criteria (Table 2) have been satisfied and the patient is able to return to the ward.

Table 1 **Extended functions and observations of the recovery room.**

| Additional function | Observation | Comment |
|---|---|---|
| Nausea | Patients vomits or complains of nausea | If not already administered, anti-emetic may be needed<br>Aspirate from nasogastric tube if present |
| Pain | Pain score high or verbal complaint of pain | Administer prescribed analgesia/start regime after checking previous administration<br>If shivering, see below |
| Hypothermia | Patient shivering, complains of cold<br>Rectal temperature decreased | Apply warm air blower or reflective 'space' blanket<br>Shivering can occur after GA when normothermic.<br>Shivering increases oxygen requirements |
| Hyperthermia | Patient may feel hot, may be sweating or have a tachycardia | Measure temperature<br>May indicate transfusion reaction, sepsis or malignant hyperpyrexia<br>Summon help |
| Postoperative drugs | Absent or unused drug chart | Adequate and appropriate analgesia should have been prescribed to avoid delays in administration |
| Postoperative fluids | | Sufficient fluids to cover the first 24 hours postoperatively |

## Core functions of the recovery room

In many ways, comparison can be made between the situation of the post-anaesthetic patient and that of an individual requiring resuscitation. A direct analogy exists between the principles of recovery room care and those of basic life-support. Hence, on arrival, the post-anaesthetic patient is checked for:

### Airway integrity and patency

Unless the patient arrives in the recovery room fully conscious, the anaesthetist will often have left an airway device, such as a Guedel airway, laryngeal mask or endotracheal tube, in place. The recovery room nurse must check that the airway is patent and be ready to suction secretions or vomit.

### Breathing

The patient should be breathing spontaneously, and there should be no evidence of airway obstruction. An oxygen mask should be applied and the patient attached to a pulse oximeter to check oxygen saturation. Extending the patient's neck or repositioning the airway may be helpful in treating minor degrees of airway obstruction. If airway obstruction persists, an anaesthetist should be called.

Many anaesthetics involve the use of muscle relaxant drugs and patients may be unable to breathe adequately if these drugs have not been fully reversed. Simple clinical tests such as coughing, head-raising and hand-squeezing may reveal whether there is residual muscle weakness. If residual weakness is suspected, it should be reported to the anaesthetist and treated urgently.

### Circulation

Pulse and blood pressure should now be checked. Tachycardia and hypotension may mean that the patient is hypovolaemic and requires transfusion.

The patient should remain under one-to-one supervision until consciousness is regained and he or she is able to maintain their airway.

## Extended functions of the recovery room

In addition to supervising safe return to consciousness, recovery staff ensure that the patient is not nauseated or in pain, and initiate appropriate treatment where necessary. Postoperative regimes for infusion of analgesic drugs via the epidural, intravenous or subcutaneous routes may be started. The extended functions of the recovery room staff are summarised in Table 1.

## Basic requirements

### Staffing and equipment

Recovery room staff should be highly skilled in the care of post-anaesthetic patients. They should be able to recognize and initiate basic treatment for all the problems alluded to above, both rapidly and effectively. There should be an effective call system to allow skilled help to be summoned quickly. Staff should undergo regular periods of skills retraining and re-education.

Fig. 2 **Essential equipment includes oxygen masks, airways and other anaesthetic equipment.**

Table 2 **Recovery room discharge criteria**

| Parameter | Value | Comment |
|---|---|---|
| Level of consciousness | Awake or immediately awakens to command | Patient must have recovered from the anaesthetic and has not been over-sedated by the postoperative analgesia |
| Airway | No obstruction<br>Can cough effectively and swallow secretions | Patient must be able to maintain and protect airway from secretions and vomit |
| Breathing | Respiratory rate > 10 | Adequate rate and depth of respiration necessary<br>Patient should have oxygen saturations > 95% in room air |
| Circulation | Mean arterial pressure > 65 mmHg | Patient should have warm, well-perfused peripheries, with no peripheral cyanosis<br>There should be no evidence of bleeding or hypovolaemia<br>Dressings and drains should be checked |
| Temperature | 36.5–37.5°C | Shivering can cause wound pain<br>Wet or soiled linen and bedclothes should be changed |
| Pain | Little or no discomfort | Patients should be comfortable, able to sleep or rest, but not over-sedated |
| Nausea | No nausea | See section on nausea and vomiting |

In order to fulfil their responsibilities, recovery room staff require full, modern monitoring equipment of the highest standard, piped oxygen supplies and effective suction units. Oxygen masks, airways and other anaesthetic equipment should be readily to hand (see Fig. 2).

### Discharge criteria

Before post-anaesthetic patients can safely return to the ward, they should satisfy a number of criteria (Table 2). The criteria listed are suggestions only and may vary between units and in certain clinical circumstances.

## *Clinical case 25*

A 37-year-old female patient has returned to the recovery room following laparoscopic surgery. She has a laryngeal mask airway and her breathing is shallow at a rate of 26 per minute. Despite supplementary oxygen, peripheral saturation is only 94%. Her hands and feet are warm and appear over-perfused, but her tympanic temperature is 35.5°C. She is unresponsive and fine twitching movements are observed in the upper limbs, shoulders and facial muscles.

*See comment on page 124.*

### Postoperative recovery

- The recovery room is a transition point between the operating theatre and the general ward.
- There is a dedicated nurse for every patient in the recovery room.
- Vital signs and levels of consciousness are closely monitored.
- Supplementary oxygen is provided to all patients.
- Resuscitation equipment is available and staff trained in emergency management are present.
- Patients must meet certain criteria, including adequate analgesia, before being discharged to the ward.

# Practical procedures

Many practical procedures other than the surgery itself are required during the perioperative period, ranging from straightforward to more complex procedures. Adequate training and supervision are essential when learning a new procedure.

## Peripheral venous access

Securing intravenous access for administration of fluids, drugs and blood products is essential. Likelihood of maintaining a clean site (see Fig. 1), ease of access, patient comfort, and avoidance of veins crossing joints are important considerations in choosing a site. Topical local anaesthetic preparations such as Amethocaine or EMLA® are useful in needle-phobic patients.

### Technique

Choose suitable vein and apply tourniquet proximally. Clean skin with alcohol swab. Infiltrate skin overlying vein with local anaesthetic. Hold skin taut, and insert cannula with needle through skin. (Fig. 2) Advance cannula and needle into vein until flashback obtained. Smoothly advance cannula over needle into vein. Withdraw needle and secure cannula with clean and transparent dressing. Always check patency/position with saline flush before giving drugs or starting infusion.

Fig. 1 **One consequence of not maintaining a clean injection site: phlebitis.**

Fig. 2 **Insertion of cannula.** Note proximal tourniquet.

## Central venous access

If it proves impossible to gain peripheral access, central venous cannulation may be necessary (Fig. 3). Central lines are also needed for administration of certain drugs. Central venous pressure monitoring provides a useful guide to intravenous fluid therapy. Attempted insertion of central venous lines carries the risk of significant complications, including pneumothorax, arrhythmias, air embolism, arterial puncture, infection and failure to cannulate the vein. Experienced help and supervision should be sought.

The internal jugular vein can usually be felt or balloted, and pressure may be applied if bleeding occurs. A high approach carries a low risk of pneumothorax. Subclavian vein cannulation carries a greater risk of pneumothorax, and accidental arterial puncture may be difficult to recognize and manage. The femoral vein may be useful, especially if upper body injuries are present, although it is difficult to maintain sterility. The basilic vein may be cannulated with a long line.

This procedure requires a cooperative patient and a full explanation should be given. A trained assistant must be available to help (Table 1). See also page 72.

### Insertion of internal jugular line cannula using Seldinger technique

Position patient with neck extended, head-down tilt. Clean skin with alcohol-based antiseptic. Drape area identified. Infiltrate skin and subcutaneously with lignocaine 1%. Flush cannula with saline. Insert needle at midpoint of line adjoining sternal notch and mastoid process, lateral to carotid artery. Advance needle in horizontal plane, towards ipsilateral nipple, aspirating continuously. Once venous blood easily aspirated, remove syringe. Gently feed guide wire through needle, watching ECG. Stop if any resistance. Remove needle and insert dilator over wire. Remove dilator and insert cannula over wire. Remove guidewire. Check venous blood can be aspirated from each lumen. Secure and flush with heparinized saline. CXR – rule out pneumothorax and check cannula position.

### Care of central venous cannulae

Minimal handling of the line and observance of asepsis when administering drugs and fluids reduce the likelihood of infection. Evidence of local or systemic sepsis for which there is no other identifiable source necessitates line removal (see page 73). Parenteral nutrition and blood products should ideally have a dedicated line. If a vasoactive drug such as dopamine has been infused via the cannula, care must be taken when administering other drugs or fluids as a bolus.

| Table 1 **Equipment needed for central line insertion** |
|---|
| ■ Tilting bed. |
| ■ ECG monitor. |
| ■ Sterile dressing pack. |
| ■ Sterile gown, gloves and drapes. |
| ■ Alcohol based skin preparation. |
| ■ Lignocaine 1%. |
| ■ Suitable cannula (single or multi lumen). |
| ■ Non-absorbable suture. |
| ■ Sterile transparent dressing. |
| ■ Heparinized saline flush. |
| ■ Pressure monitoring system. |
| ■ CXR facility |

(a)

(b)

Fig. 3 **Central venous cannulation. (a)** Insertion of cannula. **(b)** Cannula in situ.

To prevent a bolus of a potent drug, a volume of 10 ml should be aspirated from the line and discarded.

Removal of a central venous line carries the risk of air embolus. Head-down positioning while withdrawing the catheter reduces this risk, and a sterile occlusive dressing should be applied to the puncture site. Bleeding may be a problem on removal, so efforts to correct any coagulopathy are worthwhile.

## Arterial blood sampling

Arterial samples may be required to check adequacy of ventilation and severity of metabolic derangement. Possible sites include the radial (ideally non-dominant hand), brachial, dorsalis pedis and femoral arteries. When using the radial site check for collateral flow in the ulnar artery.

### Technique

Clean the skin overlying the artery with an alcohol swab, and infiltrate with local anaesthetic. Advance the needle through the skin into the artery proximally at a 30° angle. Aspirate the arterial sample into a heparinized syringe and analyse immediately or store on ice and transfer to the laboratory. Apply firm pressure to the puncture site for 5 minutes to prevent haematoma formation.

## Nasogastric tube insertion

Decompression of the stomach is commonly required after abdominal surgery and trauma. Nasogastric tubes may be used for feeding purposes. Orogastric tubes should be used if basal skull fracture is suspected.

### Technique

Ensure the patient is in a comfortable sitting position. Estimate the length of tubing required to reach the stomach (usually 35–40 cm). Take a tube and lubricate with lignocaine gel before inserting it gently into the nostril. Advance the tube along the floor of the nose. Once in the nasopharynx, ask the patient to swallow and continue advancing. Check that gastric contents can be aspirated and auscultate over the stomach for a gurgle on injection of air. Secure firmly in place and check the position of the tip of the tube on X-ray.

## Bladder catheterization

Open a sterile catheterization pack. Don sterile gloves and clean exposed genital area thoroughly. In male patients it may be necessary to retract the foreskin. Aim to keep one hand clean throughout the procedure to use for catheter insertion. Insert lignocaine gel into the urethral opening and wait for it to take effect. Remove the tip of the catheter wrapping, and gradually insert the catheter into the urethra directly from the wrapper in order to minimize handling.

In females the urethra is short and the procedure should be straightforward. In males insertion may be tricky, but elevation of the shaft of the penis may help to straighten out the urethra (see Fig. 4). Stop if resistance is felt or the procedure is painful. Once the catheter is inserted fully inflate the balloon with 10 ml sterile water. Stop if this causes pain as the balloon may still be in the urethra. Replace the foreskin if it is retracted.

Urine should flow as soon as the catheter is in the bladder, but sometimes the outlet becomes blocked with gel. Gentle suprapubic pressure, aspiration or flushing should solve the problem.

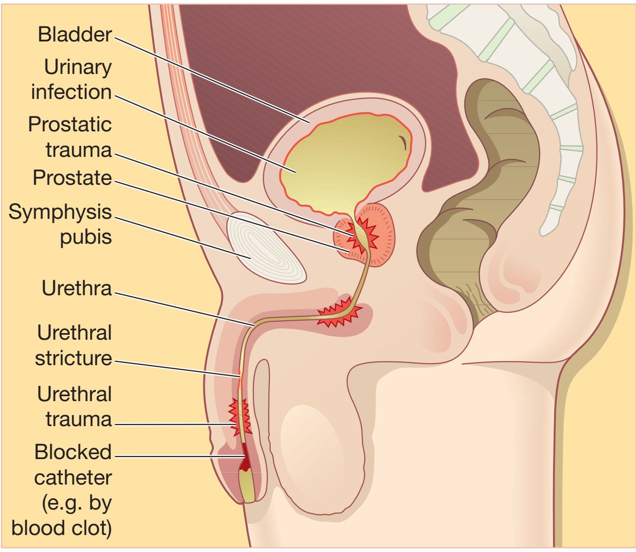


Fig. 4 **Male bladder catheterization route and potential pitfalls.**

**Practical procedures**

- Always explain procedures to awake patients.
- Maintain aseptic technique.
- Use local anaesthetic/analgesia as required.
- Only carry out procedure for which you have received adequate training
- Seek help if the procedure proves difficult.